Safety features for an automated retractable car roof design

Group: 1a

RATIONALE FOR SAFETY FEATURES IMPLEMENTED

The following safety features and their respective sensors prioritize the safety of the passengers and prevent any permanent damage to the convertible roof mechanism.

Safety feature 1 ensures that there is sufficient space above the car to enable the convertible roof to completely open and close without interference. Insufficient space to open/close the roof could cause permanent damage to the mechanism and harm to the passengers present. It is also difficult for the driver to anticipate whether there is sufficient space above the car with the naked eye and therefore the ultrasonic sensor barrel accurately measures the available distance above the car. The longevity of the sensor itself is also considered as the top of the sensor is fitted with a grill and waterproof mesh to protect it from weathering while not sacrificing the performance of the sensor's laser.

Safety feature 2 uses the outputs of an analogue and digital sensor to prevent strong headwind forces from damaging the convertible roof. The hall effect sensor is programmed to record wheel revolutions and hence, preventing the roof from opening at dangerous speeds. However, the hall effect sensor does not measure wind speeds which is an important consideration before initiating the opening/closing process. Consequently, an airflow sensor was chosen to measure the speed of wind flowing through the sensor for speeds up to 25mph. The convertible roof is designed to withstand wind speeds up to 20mph at a travelling speed of 20mph and hence this safety feature incorporates two different inputs from the sensors to the microcontroller to terminate the motor rotation if need be.

Safety feature 3 includes the use of a capacitive proximity sensor placed on the metal frame where the roof attaches when it is closed. This sensor ensures the travel path of the roof is clear of any possible debris that would harm the folding mechanism. This safety feature considers the safety of the passengers by preventing the possibility of any human interference such as a finger. The technology in the proximity sensor chosen allows the sensor to detect a change in capacitance in the electrical field around the metal frame when the obstacle is 8mm away from the frame. This further reduces the chances of a human body part such as a finger from getting caught in the roof's travel path as the mechanism will terminate when the finger is just 8mm away from the metal frame. Furthermore, the presence of high winds and rain will not affect the performance of this sensor as it would not produce a high enough capacitance to produce a HIGH output to the microcontroller.

DESCRIPTION OF OPERATION

<u>Safety feature 1: Detection of available distance above the car.</u>
The ultrasonic sensor barrel is seamlessly placed on top of the car near the windshield with the laser pointing upwards. The sensor emits an ultrasonic beam to the surface

above the car and measures the time it takes for the beam to reflect off the surface and back to the sensor, hence the distance is calculated. The source code calculates the distance using the recorded duration of the laser beam's reflection, the distance input is received by the microcontroller on port D7. When the switch to initiate the folding process is pressed, the microcontroller will signal the actuator to turn off the motor if the calculated distance is less than 253mm (swept height of the roof) meaning that there is insufficient folding space.

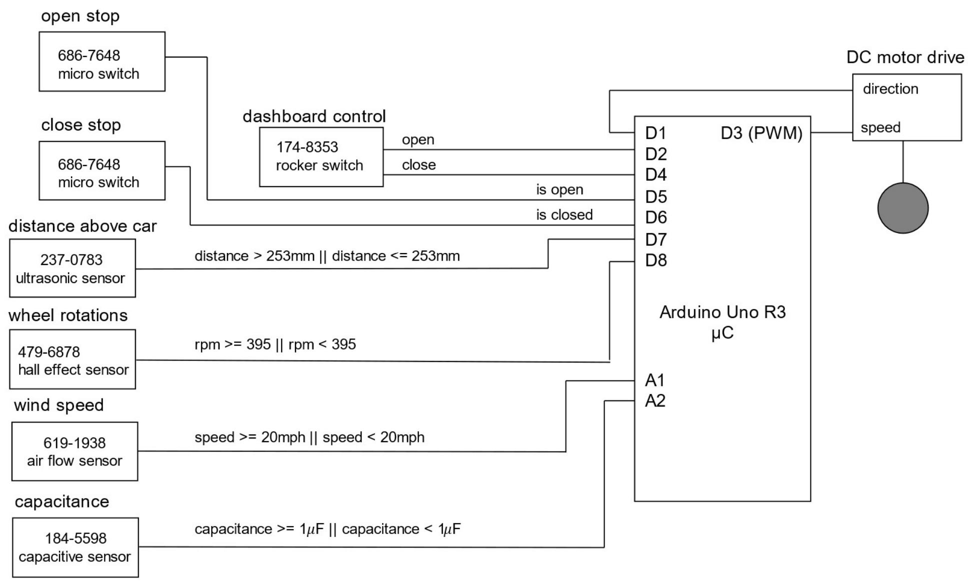
Safety feature 2: Monitoring of the car's speed and headwind speed.
A magnet is fitted on one wheel with a hall effect sensor parallel to it, every time the magnet is present in the electromagnetic field of the sensor it records a revolution. The headwind speed is calculated by the airflow sensor placed within the front grill of the car. The hall effect sensor and flow controller work together to prevent the roof from opening at dangerous wind speeds sending inputs to ports D8 and A1, respectively. The Arduino code records how many times the hall effect sensor is tripped in a minute and a formula is used to determine the wind speed in mph based on the input from the airflow sensor. The microcontroller signals the actuator to turn off the motor if the calculated wheel rpm is greater than 395rpm (20mph car speed) or the calculated wind speed is greater than 20mph.

Safety feature 3: Detection of obstacles in the roof's travel path.
The capacitive proximity sensor is placed on the metal frame of the roof attachment points. The metal frame on the top of the car acts as one plate of a capacitor which changes in value when an obstacle, such as a finger, makes contact with the metal frame. The sensor outputs LOW (0 Volts) when the capacitance is below 1μF and HIGH (5 Volts) when it is above 1μF. A human finger produces a capacitance between 1μF - 2μF and hence the sensor will not misinterpret strong winds or rain as an obstacle as it will not produce a high enough capacitance. A HIGH output from the sensor results in a HIGH input on port A2 on the microcontroller, which will signal the actuator to turn off the motor if the capacitance reading is HIGH.

SENSORS

RS Catalogue number	Description	Image
237-0783	Ultrasonic sensor barrel	
479-6878	Ratiometric hall effect sensor	
619-1938	Omron flow controller	
184-5598	Capacitive proximity sensor	

HARDWARE SCHEMATIC DIAGRAM



Notes
1. part numbers from RS catalogue
2. D1 == true (output) opens the roof
3. D2, D4, D5, D6, D7, D8 configured as digital input ports
4. A1, A2 configured as analogue input ports
5. D3 used for PWM output (PWM 3)
6. Arduino Uno R3 used (only ports in -use are labelled on the Arduino)

Automated car roof hardware schematic			
Drawing 1 of 1		not to scale	
Checked DI	Version 2	Date 17 Apr 2022	For UoB

MICROCONTROLLER EMBEDDED SOURCE CODE

```
/*
* Automated car roof embedded controller code
*
* refer to hardware schematic for port assignment
* Author: DI
* Version 2
* Date: 19/04/2022
* Modified by DI
*/

void setup() {
  // Configuration of ports as either inputs or outputs
  pinMode (1, OUTPUT);
  pinMode (3, OUTPUT);
  pinMode (2, INPUT) ;
  pinMode (4, INPUT) ;
  pinMode (5, INPUT) ;
  pinMode (6, INPUT) ;
  pinMode (7, INPUT) ;
  pinMode (8, INPUT) ;
  pinMode (9, INPUT) ;
  pinMode (10, INPUT);
  Serial.begin(9600) ;
}

int ultrasonic = 7; // Initialize pin D7 as input from ultrasonic
sensor
```

```
int duration = 0; // Sets initial signal duration from ultrasonic
sensor to 0s
int distance = (duration/2)/28.5; // Distance formula that uses
MEASURED signal duration from ultrasonic sensor
int capacitive = 10; // Initialize pin A2 as input from capacitive
sensor
int capacitance = 0; // Variable that reads the value from the
capacitive sensor
int airflow = 9; // Initialize pin A1 as input from the air flow
sensor
int halleffect = 8; // Initialize pin D8 as input from hall effect
sensor
float revolutions=0; // Sets initial wheel revolutions to 0
int rpm=0; // Sets initial wheel rpm to 0
long  startTime=0; // Sets start time for hall effect sensor
tachometer to 0s
long  elapsedTime; // Variable for total elapsed time of hall effect
sensor tachometer

void loop() {
  duration = pulseInLong(ultrasonic, HIGH); // Measures time it takes
for one pulse from the ultrasonic sensor
  capacitance = analogRead(capacitive); // Reads capacitance value
from capacitive sensor
  if (digitalRead(2) == HIGH) {
    digitalWrite(1, HIGH) ;
    analogWrite(3, 225); } // Turns on motor if switch is pressed to
open the roof
  else if (digitalRead(4) == HIGH) {
    digitalWrite(1, LOW) ;
    analogWrite(3, 255) ; } // Turns on motor if switch is pressed to
close the roof
  int windADunits = analogRead(airflow); // Reads airflow value from
air flow sensor
  float windMPH = pow((((float)windADunits - 264.0) / 85.6814),
3.36814); // Wind formula that reads input from air flow sensor and
outputs wind speed in mph
  startTime = millis();
  rpm = (max(1, revolutions) * 60000) / millis()-startTime; //
Formula that calculates rpm using hall effect sensor readings and
elapsed time of wheel revolutions
  if (windMPH >= 20 || rpm >= 395 || distance <= 25.3 ||
capacitance >= 1 || digitalRead(5) == HIGH || digitalRead(6) == HIGH)
{
    analogWrite(3, 0) ; } // Turns off motor if wind speed >= 20mph
OR wheel rotations >= 395 RPM (car speed: 20mph) OR distance above
car is <= than 253mm OR capacitance >= 1 microFarad OR if either end
stop is reached
}
```